Interactions of Herbicides and Nematicides with Root Diseases of Turnip Grown for Leafy Greens

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ABSTRACT

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The effect of three herbicides and two nematicides on root diseases of turnip grown for leafy greens was studied in a greenhouse and in environmental chambers. Soils were artificially infested with *Rhizoctonia solani*, *Pythium* spp., *Fusarium solani*, *Fusarium oxysporum*, and *Colletotrichum* sp. or were naturally infested field soils. Root diseases were caused primarily by *Pythium* spp. (mostly *P. irregulare*), *Rhizoctonia solani*, *Fusarium solani*, and *F. oxysporum* in naturally infested soils. Plant stands and foliage weights were decreased and root disease indices (RDI) were increased most by treatments with O-ethyl S, S-dipropyl phosphorodithioate (ethoprop), ethoprop + dimethyl tetrachloroterephthalate (DCPA), and 2,4,-dichlorophenyl-*p*-nitrophenyl ether (nitrofen). In some tests DCPA and *a*, *a*, *a*-trifluoro-2,-6-dinitro-*N*, *N*-dipropyl-*p*-toluidine (trifluralin) also increased the RDI and decreased foliage weight. Ethoprop + trifluralin and 1,2,-dibromo-3-chloropropane (DBCP) did not increase the RDI. *Pythium* spp. were isolated most frequently from seedlings grown in soil treated with ethoprop + DCPA. Populations of *Pythium* spp. and *F. solani* were negatively correlated with plant stands in naturally infested soils. Temperature did not influence pesticide-root disease interactions.

Additional key words: *Fusarium roseum* 'Equiseti'.

Turnip [*Brassica campestris* Ssp. *rapifera* (Metzg.) Sinsk.] is grown for both leafy greens and roots in the southern United States. Root diseases may severely reduce stands, especially when temperatures are 21-32 C (19). The most virulent pathogen is *Rhizoctonia solani* Kühn, but *Pythium irregulare* Buis, causes severe injury at low temperatures (10-21 C) and *Fusarium solani* (Mart.) Appel & Wor. is pathogenic at high temperatures (21-32 C). Significant root injury also may be caused by *F. oxysporum* Schlecht. and *Sclerotium rolfsii* (19).

Root diseases may be particularly severe in intensive cropping systems including one or two crops of turnips per year (21), and herbicide-related injury has been observed (22). Interactions between root diseases and herbicides and nematicides were previously reported in snapbean in soils of the Georgia Coastal Plain (20), and interactions between herbicides and plant pathogens have been documented in several other crops (11). Limited information is available on the influence of nematicides on root diseases caused by fungi; 1,2-dibromo-3-chloropropane (DBCP) and O-ethyl *S*,*S*-dipropyl phosphorodithioate (ethoprop) reduced the severity of root disease in some crops (1, 2, 15). This research was undertaken to determine if interactions occur between root diseases and soil pesticides in turnip.

MATERIALS AND METHODS

Soil infestation.—Cultures of *R. solani*, *F. oxysporum*, *F. solani*, *P. irregulare*, *P. ultimum* Trow, and *Colletotrichum* sp. were isolated from turnip seedlings, and grown 12 or 13 days on 3% cornmeal sand (w/w) (CMS) in 250-ml Erlenmeyer flasks at 20-25 C. Dothan loamy sand (DLS) (~ 85% sand, 7.5% silt, and 7.5% clay) collected from a fallow field, air-dried, and stored 17 mo at 29-37 C was used as a disinfested control soil in one experiment. In a second experiment, soil was used after exposure to dry heat at 80-85 C for 16 hr. Soil was infested by thoroughly blending it with CMS inoculum at 1:170 (v/v). The soil contained approximately 1.6% organic matter, had a pH of 5.8 in water, and a bulk density of 1.4 g/cm^3 after potting. Fertilizer was added to give approximately 40, 100, and 200 μg/kg of soil of N, P, and K, respectively, including residual fertility.

In the first experiment cultures of fungi were added separately to the stored, disinfested soil. Controls were the disinfested soil and a naturally infested Fuquay loamy sand (FLS) collected in a fallow field 5 mo following harvest of a crop of spinach. In a second experiment the following naturally infested soils were collected from soils with cropping histories as follows: (i) Tifton loamy sand (TLS) that had been cropped for 4 yr to an annual sequence of turnip-corn-turnip, then fallow one year, (ii) FLS underneath mature, standing corn plants 1 yr following peanuts, and (iii) FLS from a field that lay fallow for 3 yr. Soils were sieved (5 mm sieve openings) before using.

Pesticide treatments.—Pesticide dosages based on manufacturers field recommendations, and stated in kilograms active ingredient per hectare (ha) were:

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trifluralin, 0.56; DCPA, 8.96; nitrofen, 3.36; ethoprop, 8.96; and DBCP, 4.9. Trifluralin, DCPA, and nitrofen are herbicides whereas ethoprop and DBCP are nematicides. One kg/ha (15 cm deep) is equivalent to 0.5 μg/kg of soil. Ethoprop was applied in 10% granules, DBCP as a 70% emulsifiable concentrate, trifluralin as a 44.5% emulsifiable concentrate, DCPA as a 54.7% flowable liquid or a 75% wettable powder, and nitrofen as a 50% wettable powder.

Split-plot experiments with a randomized complete block design were used. Soils (artificially or naturally infested) were whole plots (four replicates) and pesticides were subplots. Soil (10-20 liters) was mixed with fertilizer for 5-10 min in a Homart® concrete mixer, Model 713.75240. After being mixed, 460 ml of nontreated soil was placed in 10-cm-diameter pots for control, DBCP, DCPA, and nitrofen treatments. For subsequent trifluralin treatments, only 200 ml of soil was placed in the bottom of each pot; sufficient soil to provide the other 260 ml per pot was removed from the mixer and retained for later treatment with trifluralin. Soil remaining in the mixer was treated with ethoprop; 460 ml was placed in each pot for the ethoprop treatment and 210 ml in each pot for the ethoprop + trifluralin treatments. The ethoprop-treated soil remaining in the mixer was treated with trifluralin and 210 ml per pot was placed on top of the ethoprop-treated soil. Soil saved for the trifluralin treatment then was returned to the mixer, treated with trifluralin, and 260 ml per pot was placed on top of nontreated soil. Thus, trifluralin was incorporated only into the top 5-cm layer of soil, allowing roots to grow into 4 to 5 cm of nontreated soil, but ethoprop was incorporated into all of the soil. Immediately after planting, the pesticides were sprayed on the soil surface in DCPA and nitrofen treatments and injected about 8 cm deep with a syringe in DBCP treatments. Soil was watered to approximately 1/3 bar water potential and pots were placed either in a greenhouse or in controlled-environment chambers. Seed of the turnip cultivar, Purple Top White Globe, was planted 5-7 mm deep (12-15 mm in trifluralin and trifluralin + ethoprop-treated soil in one test in the chambers), 20 or 25 randomly distributed seeds per 10-cm diameter pot. Seeds were commercially treated with thiram at 1 g/kg of seed.

Plants in the chambers were grown at night-day temperature ranges of 7 ± 1 to 24 ± 2 C or 20 ± 2 C to 31 ± 2 C. Those in the greenhouse were grown at fluctuating night/day temperatures of 12 to 37 C. Light was provided 12 hr each day in the chambers, 5,000 lux at the low-temperature range in a Model 818 Freas® (GCA/Precision Scientific, 3737 West Cortland St., Chicago, Ill. 60647) low-temperature incubator and 20,000 lux at the high-temperature range in either a Model CEL 37-14 or CEL 255-6 Sherer-Gillett® (Sherer-Gillette Div., Kysor Industrial Corp., Marshall, MI 49068) controlled-environment chamber.

Assessment of root diseases.—In each experiment seedlings were removed from soil 13-23 days after planting and the roots were washed. Seedlings were blotted dry, the green weight of the foliage or the entire plants was recorded, and the roots and hypocotyls were evaluated for discoloration and decay. In experiments with naturally infested soil, root and hypocotyl sections were removed, rinsed 10-15 sec in running tap water (10 to 20 C), blotted dry on sterile filter paper and incubated on water agar in petri dishes. Hyphal-tip cultures of fungi growing from tissues were transferred to potato-dextrose agar and identified. A root disease index (RDI) was used for quantification of discoloration and decay in some tests; a 1 to 5 scale was used by which 1 = <2%, 2 = 2-10%, 3 = 11-50%, 4 = >50% discoloration and decay, and 5 = plants dead or dying. Nematodes were not assayed in naturally infested soil, and no attempt was made to determine if nematode populations were related to the RDI.

Measurements of populations of soil fungi.—In the second experiment populations of several fungi in the top 2.5-cm of soil from high-temperature treatments (20 ± 2 to 31 ± 2 C) were assayed on soil dilution plates of selective media after plants were removed. Gallic acid agar (7) was used for *Pythium* spp., modified PCNB agar (12) for *Fusarium* spp., and a medium of Schmitthenner and Williams (17) for *Penicillium* spp., *Aspergillus* spp., *Trichoderma* spp., *Mucor* spp., and *Rhizopus* spp.

Seedling diseases in soils from intensive cropping systems.—Tifton loamy sand soil was collected from field plots that had been grown in the following annual cropping systems for 3 yr: turnip-corn-snapbean; turnip-peanut-snapbean; turnip-corn-turnip; turnip-peanut-turnip; or turnip-cucumber-southern pea-turnip (22). Within each cropping system, four soil treatments were used on each turnip crop in the field: DCPA, ethoprop, DCPA + ethoprop, and a cultivated control that was not treated with herbicides or nematicides. The soil was collected in November, 8 wk after the fall crops were planted and a few days after the second cutting for leafy greens in the turnip plantings. Three subsamples of about 2 liters each were taken from the surface 15-cm of soil in each plot and combined. Then each sample was divided into three parts, and one part was pasteurized with steam at 85 to 95 C for 3 hr, one part was treated in a closed tank with methyl bromide (112 g/m^3), and the third part was used as a nontreated control. No other pesticides were added to the soil after it was collected. The soil was placed in aluminum pans (20 × 20 × 5 cm) and four rows of turnip (25 seeds/row) were planted. In each experiment the pans were arranged on a greenhouse bench in a split-split plot experiment in a randomized complete block design. Cropping systems were whole plots, soil treatments used on turnip in the field were subplots, and soil treatments after collection were subsubplots.

Three wk after planting, four or five soil samples from the top 2- to 4-cm of soil were collected between the rows in soil from the turnip-corn-snapbean and the turnip-cucumber-snapbean-turnip cropping systems. Only soils treated with DCPA or cultivated, and treated with methyl bromide or nontreated were sampled. To assay *R. solani*, potato tuber cubes (5-10 mm^3) were soaked for 1 hr in 0.015% pyroxychlor [2-chloro-6-methoxy-4-(trichloromethyl) pyridine]. Fifty g of moist soil were spread over 10 cubes in a petri plate. After incubation in soil for 5 hr at 28 C, the cubes were transferred to gallic-acid medium modified with 0.01% pyroxychlor, incubated for 24 hr at 28 C, and examined for *R. solani*.

Ten plants were removed from each soil, the loose soil was gently shaken from the roots, and the roots and hypocotyls were placed into 10 ml of tap water in a 125-ml Erlenmeyer flask. The flasks were shaken 5 min on a

Burrell® (Burrell Corporation, Pittsburgh, PA 15219) wrist-action shaker (control setting, five). Four 1-ml aliquants then were removed and each was placed on a petri plate of gallic-acid medium to determine populations of *Pythium* spp. in the rhizosphere.

RESULTS

Artificially and naturally infested soil in the greenhouse.—The most virulent pathogen on turnip seedlings in artificially infested soil was *R. solani* (Table 1). Pesticides did not influence the RDI in soils separately infested with fungi; but in disinfested soil, DBCP and ethoprop + DCPA significantly increased the RDI. In contrast, nitrofen, trifluralin, DCPA, and ethoprop increased the RDI in naturally infested soil, but DBCP and ethoprop + DCPA did not.

Plant stands were reduced by all pesticide treatments in naturally infested soil, but there were no differences among pesticide treatments in artificially infested soil. In disinfested soil only ethoprop + DCPA reduced plant stands.

The effect of the pesticide treatments on growth is reflected in the fresh weight of seedlings as shown in Table 2. The fresh weight of seedlings was negatively correlated ($P = 0.01$) with postemergence damping-off ($r = -.55$), and highly correlated with the number of seedlings showing no symptoms of root disease ($r = .83$). Without pesticides, only *R. solani* reduced growth in artificially infested soil. When pesticides were used, several pesticide vs. soil fungi interactions were evident. The following soil fungi reduced growth in artificially

TABLE 1. Root discoloration and decay in turnip seedlings in artificially and naturally infested soils treated with herbicides and nematicides

	Root disease index[x]						
	Naturally infested field soil	Artificially infested soil[y]					
Pesticides		*Rhizoctonia solani*	*Pythium* spp.	*Fusarium oxysporum*	*Fusarium solani*	*Colletotrichum* sp.	Control	Avg
Ethoprop	4.0 a	3.6	2.8	2.9	3.7	3.2	2.7 ab	3.3 a
DBCP	3.4 ab	3.5	2.6	2.4	2.0	2.9	3.3 a	2.9 b
Trifluralin	4.3 a	4.3	3.1	2.4	2.8	2.9	2.2 b	3.2 ab
DCPA	4.2 a	3.5	2.9	2.9	1.9	2.4	2.0 b	2.8 b
Nitrofen	4.4 a	3.5	3.5	3.1	3.1	3.3	2.9 ab	3.4 a
Ethoprop + DCPA	3.8 ab	3.4	3.1	2.4	3.8	2.9	3.5 a	3.3 a
None	3.0 b	3.4	2.8	2.7	2.9	2.8	2.0 b	2.8 b
Avg[z]	3.9	3.6	3.0	2.7	2.9	2.9	2.7	

[x] Root Disease Index: 1 = <2%, 2 = 2-10%, 3 = 11-50%, and 4 = >50% of the root and hypocotyl tissues discolored or decayed; and 5 = dead plants. An average of four replications of Purple Top White Globe, 25 seeds per replicate. Data were taken on all emerged seedlings 13 days after planting. Numbers within a column followed by the same letter are not significantly different according to Duncan's multiple range test, P = 0.05.

[y] Dothan loamy sand, stored 18 mo to reduce inoculum densities of soilborne pathogens to very low levels, was artificially infested with fungi grown on 3% cornmeal sand (w/w). Naturally infested Dothan loamy sand was collected from a fallow field planted to spinach and cabbage during the previous 2 yr.

[z] Numbers above the same line are not significantly different, $P = 0.05$.

TABLE 2. Fresh weight of turnip seedlings grown in artificially and naturally infested soils treated with soil pesticides

	Fresh weight of seedlings (g) grown in soil treated with:							
Soil treatment[x]	Control	DBCP	DCPA	Trifluralin	Ethoprop	DCPA + Ethoprop	Nitrofen	Avg
Artificially infested:								
Rhizoctonia solani	0.4 b[y]	0.6 d	0.7 c	0.1 e	0.7 cd	0.9 b	0.8 bc	0.6 c
Pythium spp.	2.3 a	2.5 a	2.0 b	1.4 cd	2.2 a	1.4 ab	1.1 abc	1.9 a
Fusarium oxysporum	2.7 a	2.4 ab	1.9 b	2.2 ab	1.5 abc	1.9 a	1.7 a	2.0 a
F. solani	2.2 a	2.3 ab	2.5 ab	2.5 ab	1.2 bcd	1.0 b	1.9 a	1.9 a
Colletotrichum sp.	2.5 a	2.5 a	2.0 b	1.8 bc	1.3 bcd	1.3 ab	1.6 ab	1.8 a
Control	2.5 a	1.6 bc	2.9 a	2.7 a	1.7 ab	1.2 ab	1.6 ab	2.0 a
Naturally infested:	1.9 a	1.4 c	0.9 c	0.7 de	0.6 d	0.8 b	0.5 c	1.0 b
Avg[z]	2.1	1.9	1.9	1.6	1.3	1.2	1.3	

[x] Dothan loamy sand, stored 18 mo to reduce inoculum densities of soilborne pathogens to very low levels, was artificially infested with fungi grown on 3% cornmeal sand (w/w). Naturally infested Dothan loamy sand was collected from a fallow field planted to spinach and cabbage during the previous 2 yr.

[y] Numbers in each column followed by the same letter are not significantly different according to Duncan's multiple range test, $P = 0.05$.

[z] Numbers above the same line are not significantly different, $P = 0.05$.

infested soils compared with the disinfested control: *Pythium* spp., *F. oxysporum*, and *Colletotrichum* sp. in soil treated with DCPA; and *Pythium* spp., and *Colletotrichum* sp. in soil treated with trifluralin. In contrast, growth was enhanced by the soil fungi in soil treated with DBCP. In naturally infested soil, DCPA, ethoprop, trifluralin, and nitrofen reduced plant growth compared with that in disinfested soil. Nitrofen caused severe leaf burn in all soils.

Naturally infested soil in environmental chambers.—Root diseases were increased the most by ethoprop and ethoprop + DCPA treatments (Table 3). In addition, trifluralin and ethoprop + trifluralin treatments significantly increased the RDI when seeds were planted 12-15 mm instead of 5-7 mm deep. However, a control planted 12-15 mm deep was not included in the experiment, so the influence of planting-depth alone on the RDI in nontreated soil was not determined. The ethoprop treatment reduced growth but did not influence stand of plants, whereas the ethoprop + DCPA treatments did not reduce growth or stand of plants but significantly increased postemergence damping-off to 21% compared with 9% in nontreated soil. The incidence of root disease, growth, and plant stands were not significantly influenced by DBCP, DCPA, trifluralin, or ethoprop + trifluralin treatments. There was a highly significant ($P = 0.01$) negative correlation ($r = -.71$) of green foliage weight with the RDI.

Plant growth was much greater in the pasteurized soil than in the field soils, and the RDI was less than in two of the three field soils. Postemergence damping-off was 15 to 25% in the fields soils compared with only 2% in the pasteurized soil.

Emergence after 5 days was less at low (7 ± 1 night, 24 ± 1 C day) than at high (20 ± 2 night, 31 ± 2 C day) temperatures, but there were no differences after 9 days. Temperature did not affect the RDI, growth, or plant stands.

There were significant ($P = 0.05$) soil-pesticide interactions in stands of plants (Table 4) and postemergence damping-off. Treating with ethoprop only decreased stands in fallow FLS, whereas treating with ethoprop + DCPA only decreased stands in FLS collected underneath mature, standing corn plants. The most sparse stands were in TLS previously in turnip-corn-turnip (then fallow), but pesticide treatments did not influence stands in that soil. In the DLS control, stands were reduced only in the two treatments in which the seeds were planted 12 to 15 mm deep. There were no differences in postemergence damping-off in the DLS control or the TLS, but the ethoprop + DCPA treatment significantly increased damping-off in the FLS collected under corn as compared with the control (1 vs. 27%). The trifluralin (deep planting) and ethoprop + trifluralin (deep planting) treatments both increased damping-off relative to the nontreated control in FLS collected under corn, but in fallow FLS only the latter treatment caused significantly more damping-off than the nontreated control.

Populations of *Pythium* spp., *F. solani*, *F. oxysporum*, *F. roseum* Link, *Penicillium* spp., *Mucor* spp., *Rhizopus* spp., and *Trichoderma* spp. were significantly greater in one or more field soils than in the pasteurized control, but there were no differences in populations of *Aspergillus* spp. Populations of *R. solani* were 0.6 to 1.1 propagule/10 g of moist soil in the naturally infested soils, but *R. solani* was not detected in the pasteurized soil. None of the pesticide treatments significantly influenced populations of the fungi assayed. In naturally infested soils treated with ethoprop, or ethoprop + DCPA, or nontreated, the populations of *Pythium* spp. averaged 104, 190, and 95 propagules/g, respectively. Populations of *F. solani* in soil were highly correlated ($P = 0.01$) with the RDI ($r = .53$) and populations of *Pythium* spp. were highly correlated with postemergence damping-off ($r = .58$) in high-temperature treatments. Stands of 21-day-old plants were negatively correlated ($P = 0.01$) with the RDI ($r = -.74$), and populations of *F. solani* ($r = -.42$) in soil. Populations of other fungi assayed were less significantly correlated, or not correlated, with the RDI, postemergence damping-off, and plant stands.

Fungi were isolated from 23-30 seedlings from each pesticide treatment in infested field soils; 53, 68, 48, and 37% of the seedlings grown in soils treated with ethoprop, ethoprop + DCPA, and ethoprop + trifluralin (deep planting), or nontreated, respectively, yielded *Pythium* spp. *Fusarium oxysporum* also was occasionally isolated from seedlings in each treatment, but other fungi were rarely isolated.

TABLE 3. Influence of soil pesticides on root diseases, green foliage weight, and number of plants in three naturally infested soils and a pasteurized soil[w] in a greenhouse and environmental chambers[x]

Pesticides	RDI[y]	Foliage fresh wt (g)[z]	Number of plants 12-21 days	
			Alive	Dead
None	1.9 a	7.5 a	14.5 a	1.6 bcd
Trifluralin (T)	2.3 ab	5.7 abc	13.5 a	1.6 bcd
Trifluralin-d	2.9 de	3.2 cd	8.9 b	2.1 ab
DCPA	2.1 ab	6.4 ab	14.0 a	0.9 d
Ethoprop (E)	2.8 cde	4.0 bc	12.2 a	2.2 abc
DBCP	2.2 ab	7.4 ab	14.1 a	1.1 cd
E + T	2.4 abcd	4.7 abcd	13.1 a	1.9 abcd
E + T-d	3.2 e	1.8 d	6.4 c	2.6 a
E + DCPA	2.5 b	4.5 abcd	11.9 a	3.1 a

[w] The following four soils were used: Fuquay loamy sand, collected underneath mature, standing corn plants, or in an adjacent fallow field; Tifton loamy sand, planted in annual cropping sequences of turnip-corn-turnip for 4 yr, then fallow 1 yr before it was collected; and Dothan loamy sand, collected in a fallow field and exposed to dry heat in an oven for 16 hr at 80-85 C.

[x] Seeds were planted 12-15 mm deep in trifluralin-d and ethoprop + trifluralin-d treatments and 5-7 mm deep in the other treatments. Numbers in each column followed by the same letter are not significantly different according to Duncan's multiple range test, $P = 0.05$.

[y] The abbreviation RDI = Root Disease Index in which 1 = <2%, 2 = 2-10%, 3 = 11-50%, and 4 = >50% of the root and hypocotyl tissues discolored or decayed; and 5 = dead plants. Average of two replications on each soil.

[z] Foliage weights, from 20 ± 1 night, 31 ± 2 C day only. Data on number of plants is a combination of two replications at temperatures of 7 ± 2 night, 24 ± 2 C day and two replications at temperatures of 20 ± 1 night and 31 ± 2 C day. Temperature did not influence plant stands.

Intensive cropping systems.—There were no significant differences among the soils collected from the five cropping systems (22 days after planting) in postemergence damping-off, plant stands, or foliage fresh weights. Plants in field soils that had been treated with a nematicide + a herbicide produced more foliage than plants treated with a nematicide or herbicide alone, or the cultivated control, but there were no differences in postemergence damping-off or plant stands. Postemergence damping-off was less in soils treated with methyl bromide or pasteurized with steam (3%) than in nontreated soil (10%), but soil treatments did not influence foliage weights or final plant stands.

Rhizoctonia solani was not isolated from potato cubes incubated in the soils. There were more propagules of *Pythium* spp. per gram of rhizosphere soil in the turnip-corn-snapbean system than in the turnip-cucumber-southern pea-turnip system (615 vs. 55), and significantly more *Pythium* spp. were isolated from seedlings from the former system than from the latter (34 vs. 7%). An increase in populations of *Pythium* spp. was correlated ($P = 0.05$) with a decrease in foliage weight ($r = -.48$), but the isolation of *Pythium* spp. from seedlings was not. More *Pythium* spp., *F. oxysporum*, and *R. solani* were isolated from plants grown in herbicide-treated soil than in cultivated soil, but there were no differences in plant stands and foliage weights.

Field plots.—Turnip was planted in a field of DLS in October and treated with DCPA (75% wettable powder), DCPA (54.7% flowable liquid) (8.96 kg/ha) or nontreated. Seedlings were examined when they were 22 days old. The RDI was 1.8 in the nontreated control and 2.6 to 2.8 in the plots treated with DCPA. The plants in control plots were 9 cm tall vs. 5 cm tall in the plots treated with DCPA. All plants were green, and no symptoms of phytotoxicity were observed. Several different fungi were isolated from the seedlings, but the only differences among treatments were in the percentage of seedlings yielding cultures of *F. roseum* 'Equiseti' (13% in the controls vs. 52% in the DCPA-treated plots). We did not study possible interactions between *F. roseum* 'Equiseti' and DCPA in tests in controlled-environment chambers.

DISCUSSION

Our research indicates that interactions of pesticides with soil fungi may contribute to increased damping-off and decreased growth and yields of turnip grown for leafy greens. Ethoprop, DCPA, trifluralin, nitrofen, and ethoprop + DCPA caused a significant increase in root rot or a decrease in growth in one or more soils, but only ethoprop and ethoprop + DCPA consistently increase root diseases and reduced growth. Because DCPA alone was less detrimental than ethoprop or ethoprop + DCPA, the effect of the ethoprop + DCPA treatments was probably caused by ethoprop rather than synergism of the two pesticides.

Ethoprop appeared to interact with *F. solani* and *Pythium* spp. to increase root disease and decrease growth in turnip. *Fusarium solani* and *Pythium* irregulare are pathogenic on turnip seedlings and are commonly isolated from turnip seedlings in the Georgia Coastal Plain (19). In snapbean, ethoprop increased root rot in soil infested with *Pythium* spp., and foliage weight was reduced in soil infested with *F. solani* (20). However, ethoprop reduced damage by *Sclerotium rolfsii* in peanut field studies, and inhibited growth of *R. solani* in petri plates of field soil (15). In our tests, none of the pesticides used reduced the severity of root rot in soil artificially infested with *R. solani*. *Rhizoctonia solani* is the most virulent pathogen of turnip seedlings in the Georgia Coastal Plain, especially at high temperature (19) and it is frequently isolated from seedlings in fields receiving high amendments of organic matter. Ethoprop is not used for nematode control in turnip, but it is used on tobacco, soybean, peanut, corn, and sweet potato in the Georgia Coastal Plain.

TABLE 4. Number of 12- to 21-day-old live turnip seedlings in three naturally infested field soils and a pasteurized soil treated with soil pesticides [x]

	Soil and previous crop[y]			
Pesticides[z]	FLS, corn	TLS, turnip-corn-turnip, fallow	FLS, fallow	DLS, control
None	15.5 a	12.0 ab	13.2 ab	17.2 a
Trifluralin (T)	14.8 ab	8.8 b	15.5 a	15.0 a
Trifluralin-d	10.5 bc	8.8 b	11.2 abc	5.0 b
DCPA	15.8 a	11.5 ab	13.8 ab	15.0 a
Ethoprop (E)	13.2 ab	11.2 ab	8.5 c	15.8 a
DBCP	12.5 abc	13.8 a	15.0 a	15.2 a
E + T	14.0 ab	10.2 ab	12.5 abc	15.8 a
E + T-d	8.5 c	8.0 b	3.0 d	6.2 b
E + DCPA	10.2 bc	10.5 ab	9.8 bc	17.2 a

[x] Average of two replications each at low-range temperatures of 7 ± 1 night, 24 ± 2 C day, and high-range temperatures of 20 ± 1 night, 31 ± 2 C day. Temperature did not significantly influence number of seedlings.

[y] Abbreviation of soil names: FLS = Fuquay loamy sand, collected underneath mature, standing corn plants or in an adjacent fallow field; TLS = Tifton loamy sand, planted in annual cropping sequences of turnip-corn-turnip for 4 yr, then fallow one year before it was collected. DLS = Dothan loamy sand, collected in a fallow field and exposed to dry heat in an oven for 16 hr at 80-85 C.

[z] Seeds in the Trifluralin-d and E + T-d treatments were planted 12-15 mm deep; seeds were planted 5-7 mm deep in the other treatments. Numbers in each column followed by the same letter are not significantly different according to Duncan's multiple range test, $P = 0.05$.

In our greenhouse tests, DCPA reduced seedling weights and increased root disease in only one naturally infested soil in one test. Because we observed no differences in DCPA-treated and nontreated field soil following turnip when soil was tested in the greenhouse, we assume that the effects of the herbicide on turnip occurred soon after it was applied. The half-life of DCPA in Dothan loamy sand in field tests at Tifton is 35 to 50 days (Tom Zavesky, Diamond Shamrock Chemical Co., *personal communication*). Root rot of snapbean was increased in DLS infested with *F. solani*, or a combination of fungi (20), but we are unaware of other reports of DCPA increasing root disease. Just the opposite was reported by Romney et al. (16) in onion and bean; seedlings grown in soil treated with DCPA were less susceptible to the northern root-knot nematode than seedlings grown in nontreated soil. They suggested resistance to the nematode was caused by altered cell structure of the root epidermis, increased root exudate as evidence by soil adherence, or reduced fibrous root development, or a combination of the preceding factors. Others have reported that DCPA does not influence populations of soil microorganisms (6, 23), and we found no differences in populations of soil fungi in soil treated with DCPA in an experiment in an environmental chamber. Phatak (13) reported that DCPA did not influence emergence of rutabaga (*Brassica naprobrassica* Mill.) in greenhouse studies, and we saw no influence of the herbicide on emergence and plant stands. More *F. roseum* 'Equiseti' was isolated from turnip seedlings in field plots treated with DCPA, but the fungus was not pathogenic on turnip in other tests when chemicals were not used (19).

In contrast to DCPA, trifluralin interacts with root diseases of many plants (11). It lowered the incidence of clubroot of cabbage, but only at dosages much higher than would ordinarily be used in the field (3). The herbicide also reduced injury by *R. solani* in eggplant, tomato, and pepper (9); had a variable influence on cotton and snapbean (5, 9, 20); and did not influence resistance in corn and oats (9). In addition, trifluralin reduced root rot in pea caused by *Aphanomyces euteiches* (10), and increased resistance of eggplant and tomato to *F. oxysporum* and *Verticillium dahliae* (9). In our tests trifluralin reduced growth in turnip seedlings in soil artificially infested with *Pythium* spp. and *Colletotrichum* sp., and in one naturally infested soil with high populations (267 propagules/g) of *Pythium* spp., but not in other naturally infested soils. *Colletotrichum higginsianum* causes a severe root rot of turnip grown for mature roots (18) in the Georgia Coastal Plain, and *Colletotrichum* spp. are infrequently isolated from seedlings in fields of turnip.

Root diseases were increased and plant stands reduced when turnips were planted 12-15 mm deep instead of 5-7 mm deep in soils treated with trifluralin and trifluralin + ethoprop. The interaction of soil pesticides and root diseases with depth of planting could be very important in leafy greens production and should be explored further. Precision seeding is used on only a small percentage of the commercial turnip acreage, and depth of planting may fluctuate several millimeters because of variation in seedbed preparation.

In our study, DBCP had no influence on root diseases and growth of turnip. In other research, the nematicide increased root rot caused by *P. myriotylum* in snapbean (20), but decreased root rot caused by *P. ultimum* in cotton (2) and *R. solani* in tomato (1), and inhibited growth of pythiaceous fungi in culture (4). In field tests at Tifton, DBCP reduced Fusarium wilt of okra in soil infested with *Meloidogyne incognita* (8) but did not reduce southern blight of tomato (14). The nematicide is rarely used for nematode control on crucifers in the Georgia Coastal Plain, and is probably not an important factor in root diseases of turnip, but it is commonly used on many other crops for control of nematodes.

Because root diseases of turnip can be important in intensive cropping systems in the Georgia Coastal Plain (21), the interactions of ethoprop, DCPA, and trifluralin with soil fungi may partially explain reduced growth and yields observed in field tests (22). The pesticides did not influence populations of soil fungi that we studied, but they may interact differently with other soilborne pathogenic fungi to increase or decrease inoculum densities and alter disease severity. Also, in field soils, pathogenic nematodes may play an important role in the root-disease complex of turnip.

LITERATURE CITED

1. ASHWORTH, L. J. JR., B. C. LANGLEY, and W. H. THAMES, JR. 1964. Long-term inhibition of Rhizoctonia solani by a nematicide, 1,2,-dibromo-3-chloropropane. Phytopathology 54:187-191.
2. BRODIE, B. B. 1961. Use of 1,2,-dibromo-3-chloropropane as a fungicide against Pythium ultimum. Phytopathology 51:798-799.
3. BUCZACKI, S. T. 1973. The effects of trifluralin and related dinitroaniline herbicides on clubroot of brassicae. Ann. Appl. Biol. 75:25-30.
4. BUMBIERIS, M. 1970. Effect of DBCP on pythiaceous fungi. Plant Dis. Rep. 54:622-624.
5. CHANDLER, J. M., and P. W. SANTELMANN. 1968. Interactions of four herbicides with Rhizoctonia solani on seedling cotton. Weed Sci. 16:453-456.
6. FIELDS, M. L., R. DER, and D. D. HEMPHILL. 1967. Influence of DCPA on selected soil microorganisms. Weed Sci. 15:195-197.
7. FLOWERS, R. A., and R. H. LITTRELL. 1972. Oospore germination of Pythium aphanidermatum as affected by casein, gallic acid, and pH levels in a selective agar medium. Phytopathology 62:757 (Abstr.).
8. GOOD, J. M. 1964. Effect of soil application and sealing method on the efficacy of row application of soil nematicides for controlling root-knot nematodes, weeds, and Fusarium wilt. Plant Dis. Rep. 48:199-203.
9. GRINSTEIN, A., J. KATAN, and Y. ESHEL. 1976. Effect of dinitroaniline herbicides on plant resistance to soilborne pathogens. Phytopathology 66:517-522.
10. HARVEY, R. G., D. J. HAGEDORN, and R. L. DE LOUGHERY. 1975. Influence of herbicides on root rot in processing pea. Crop Sci. 15:67-71.
11. KATAN, J. and Y. ESHEL. 1973. Interactions between herbicides and plant pathogens. Residue Rev. 45:145-177.
12. PAPAVIZAS, G. C. 1967. Evaluation of various media and antimicrobial agents for isolation of Fusarium from soil. Phytopathology 57:848-852.
13. PHATAK, S. C. 1974. Effects of herbicide-insecticide combinations on rutabaga emergence. Can. J. Plant Sci. 54:517-520.
14. RANKIN, H. W., and J. M. GOOD. 1959. Effect of soil

fumigation on the prevalence of southern blight on tomatoes. Plant Dis. Rep. 43:444-445.

15. RODRIQUEZ-KABANA, R., P. A. BACKMAN, and P. S. KING. 1976. Antifungal activity of the nematicide ethoprop. Plant Dis. Rep. 60:255-259.
16. ROMNEY, R. K., J. L. ANDERSON, and G. D. GRIFFIN. 1974. Effects of DCPA on seedling infection by root-knot nematode. Weed Sci. 22:51-54.
17. SCHMITTHENNER, A. F., and L. E. WILLIAMS. 1958. Methods for analysis of soilborne plant pathogens and associated soil fungi. Ohio Agric. Exp. Stn., Bot. and Plant Pathol. Mimeo. Ser. No. 29. 19 p.
18. SUMNER, D. R. 1971. Ecology of root rot of turnip grown for processing. Phytopathology 61:913 (Abstr.).
19. SUMNER, D. R. 1974. Ecology and control of seedling diseases of crucifiers. Phytopathology 64:692-698.
20. SUMNER, D. R. 1974. Interactions of herbicides and nematicides with root diseases of snapbean and southern pea. Phytopathology 64:1353-1358.
21. SUMNER, D. R., N. C. GLAZE, A. W. JOHNSON, and C. C. DOWLER. 1972. Root diseases of snapbeans and turnips in intensive cropping systems. Abstract No. 1076 *in* Abstracts of Papers, 2nd Int. Congr. Plant Pathol., 5-12 Sept. 1973, Minneapolis, Minnesota (unpaged).
22. SUMNER, D. R., A. W. JOHNSON, N. C. GLAZE, and C. C. DOWLER. 1973. Root diseases of snapbeans and control in intensive cropping systems. Ga. Agric. Res. 16(4):4-5, 7.
23. TWEEDY, B. G., N. TURNER, and M. ACHITUV. 1968. The interactions of soilborne microorganisms and DCPA. Weed Sci. 16:470-473.